DOE Technical Standards Program
Topical Subcommittee on Metrology

Survey of Measurement Uncertainty Analysis at DOE Laboratories

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A working group within the Technical Standards Program's Topical Subcommittee on Metrology was tasked with soliciting information from a cross section of DOE laboratories on the topic of performing uncertainty analyses. It is hoped that by understanding how other DOE laboratories are meeting the challenges of implementing uncertainty analysis programs, individual laboratories can gauge the effectiveness of their own approaches to utilizing uncertainty analysis to improve their own laboratory operations. It must be noted here that this is not a scientifically derived sampling from throughout the DOE community. A questionnaire was prepared with a series of questions designed to elicit data and perceptions regarding if and how uncertainty analyses are performed at individual sites. This questionnaire was sent to 17 DOE facilities known to engage in calibration activities by this working group. Ten responses were received and the results from this survey are summarized in this paper.

All ten respondents indicated that their laboratory performed calibrations. All laboratories also indicated that the laboratory staff included both engineers and technicians although the ratio of engineers to technicians ranged from nearly 2:1 (2 engineers for each technician) to 1:6 (six technicians for each engineer). The average of all respondents was about 2 technicians for each engineer on staff. Nine of the ten reporting laboratories pointed to ANSI/NCSL Z-540-1 as a primary quality standard while several of the labs reported secondary standards that included ANSI 323, ISO 17025, ISO Guide 25, and NQA-1. Five of the ten laboratories reported being NVLAP accredited and one accredited by A2LA. All six accredited labs indicated that uncertainty analyses performed for accredited calibrations did not differ from those performed for non-accredited calibrations.

When asked if uncertainty analyses are performed, nine of the ten reporting labs responded yes. Most of the labs indicated that the engineers performed the analyses but several emphasized that much of the data used in the analyses came from the technicians on the bench. Only three of the reporting labs stated that a standard format was used for all of their uncertainty analyses. Seven labs pointed to NIST 1297 as a guide for performing analysis while NCSL RP-12, the GUM, and Z-540-2 were each mentioned by three labs.

In response to a question that asked if uncertainty analyses were performed on calibration procedures, calibration processes, or on individual calibrated items, two labs said by items, one lab by procedure, and one lab stated their analyses were completed for each cal process. Two labs indicated that uncertainty analyses were completed for all measurement standards and the results of those analyses were used to calculate an accuracy ratio for a specific calibration. If that accuracy ratio met a minimum standard (usually 4:1) no further analysis was needed. In all, eight of the ten respondents indicated that an accuracy ratio concept is used in their labs and all eight said the ratio used is 4:1. Two of those labs indicated a TAR (test accuracy ratio) is used in the analysis of all calibrations, three said the TAR method was only applied to "lower accuracy" calibrations, and two labs indicated that a TAR calculation determined the need for a more comprehensive uncertainty analysis. That is, if a 4:1 accuracy ratio exists, no further analysis is performed.

A less uniform response was received on the question of whether a graded approach is used in the application of uncertainty analyses. The purpose of the question was to try and identify what criteria is being used to determine the need for the completion of an uncertainty analysis. Two laboratories said that they do not use a graded approach at all. One lab stated that the criteria used was whether the item being calibrated was a measurement standard or IM&TE. One other lab mentioned that the level of uncertainty was considered in determining the need for an analysis. Three labs pointed to a 4:1 TAR as their criteria for determining if a more comprehensive uncertainty analysis is needed.

Finally, the questionnaire asked if all of the uncertainty analyses that needed to be completed at the facility were completed. Eight of the ten respondents answered this question with one lab indicating that all analyses are now completed. All others stated that they have yet to complete all needed analyses with time, staff and money being the predominant reasons that the work is not completed. Four of the labs had no schedule for completing all of their uncertainty analyses, one estimated it would take 4 months, two said about 2 years, and one lab estimated three to five years.

The need for performing uncertainty analyses, as integral component of establishing and demonstrating traceability is unquestioned. The challenge to the DOE laboratory community, like in the larger measurement / calibration community is striking a balance between the ideal and the practical. Ideally we would all like to have all of our measurement processes fully characterized with all sources of uncertainty accurately quantified and well understood. A rigorous analysis of a measurement process, as described in guides such as NIST Guide 1297 or the GUM, are not only resource intensive but often require process performance data that only becomes meaningful when viewed after many calibrations are performed or after a long period of time as data on the process is collected.

If the responses received to this questionnaire represent a fair cross section of the thinking and policies in the DOE laboratory community, then it shows that the need to continue to move toward the ideal understanding, definition, and documentation of our measurement processes is almost universally accepted. There also seems to be some common threads as to how to transition to this improved calibration environment while dealing with the practical realities of limited resources and the marketplace demand for affordable calibration services. These techniques include reserving the most rigorous analyses for the most critical measurement processes. Some labs seem to define the most critical as the process for calibrating and certifying measurement standards. Others use the yardstick of the level of uncertainty to prioritize the processes or calibrations that should be scrutinized the closest.

One relic of the past that most of our laboratories are still finding useful in this new world of uncertainty analysis is the concept of Test Accuracy Ratio. In many instances, it appears, DOE laboratories use a 4:1 TAR as a preliminary analysis itself to make a determination of whether a more formal or exhaustive uncertainty analysis is warranted. For other operations, the TAR concept is applied uniformly to an entire class or type of calibration such as general purpose IM&TE or calibrations performed using an OEM procedure with OEM recommended standards. It seems almost certain that there is, and should be, a place for prudent use of this concept in any measurement or calibration program struggling to deal with the practical realities of finite resources.

Establishing and demonstrating measurement traceability requires every calibration laboratory in the traceability chain to identify, quantify, and consider all sources of error introduced during the measurement process. This potential error is expressed as a value of uncertainty. A reported measurement value or a certification that an instrument meets a specification is only meaningful when accompanied by a statement of the uncertainty associated with the measurement. The DOE calibration / measurement community has an acute awareness of the regulatory and technical requirements to continue to move to a position where all measurement processes are fully characterized and the uncertainty analyzed. All this must be accomplished while providing reliable calibrations and measurements that meet their customer's needs and expectations today.